INSTREAM FLOWS RESEARCH AND VALIDATION METHODOLOGY FRAMEWORK 2016-2017

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BIO-WEST

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University of Houston Clear Lake

BRAZOS BBASC

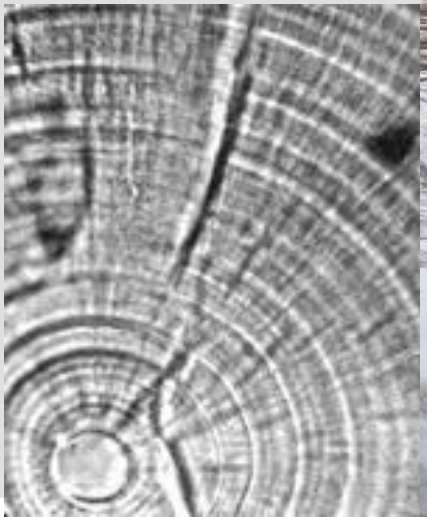
AUGUST 16, 2017

OVERVIEW

- Funded - Texas Water Development Board
  - Via the SB3 BBASC process
  - 1st round – 2014-2015
  - 2nd round – 2016-2017
- Three major basins
  - Guadalupe – San Antonio Basin
  - Colorado – Lavaca Basin
  - **Brazos Basin – including Brazos Estuary**
- Project goals:
  - To enhance the understanding of flow-ecology relationships in the three major basins
  - To initiate the process for developing a methodology for testing established flow standards

ECOLOGICAL COMPONENTS

- Aquatic
- Floodplain Connectivity
- Riparian
- Brazos Estuary



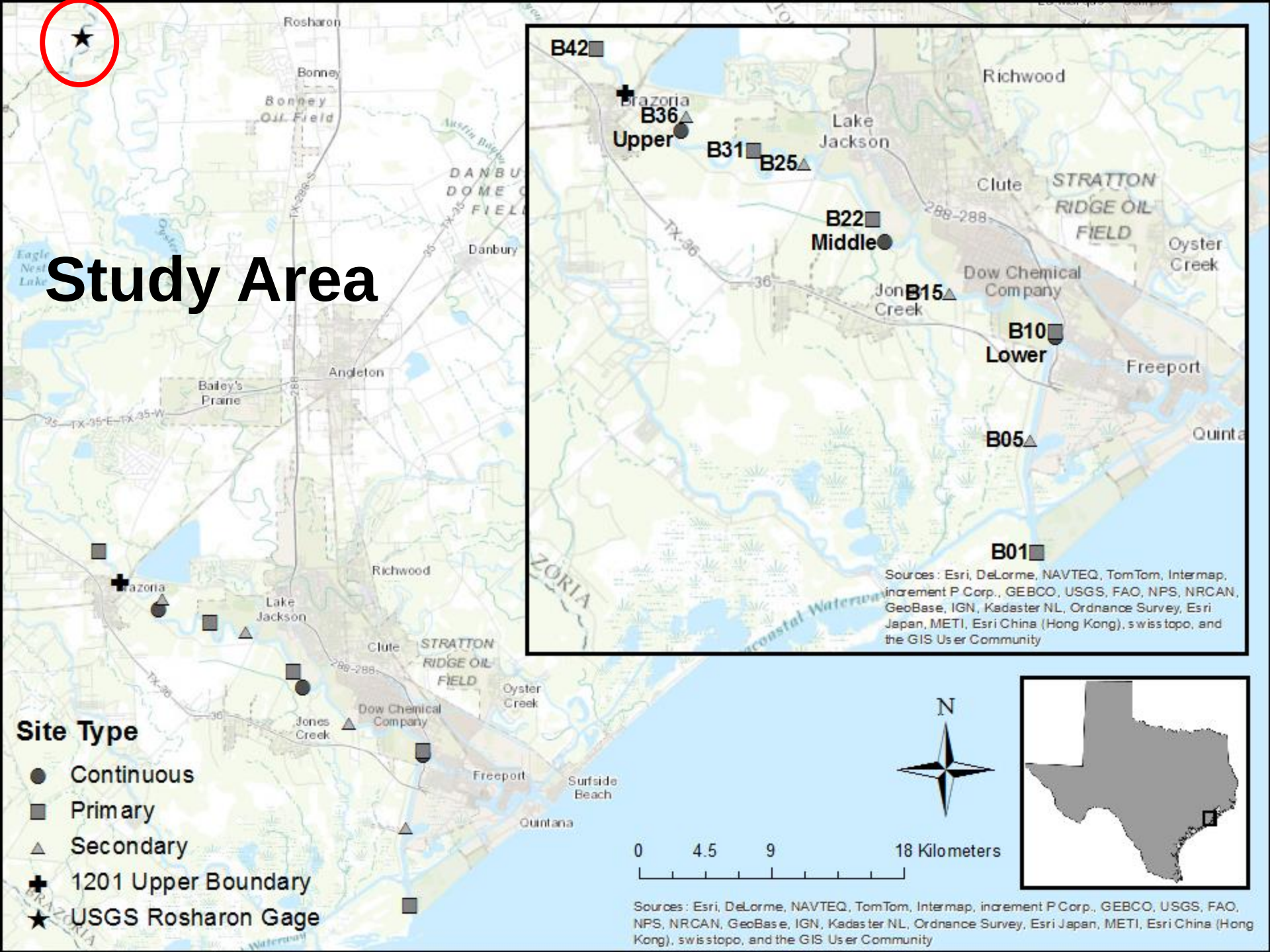
SAMPLING ACTIVITIES AND RESULTS

BRAZOS ESTUARY

- Dr. George Guillen

STUDY OBJECTIVES

1. Characterize the estuarine flow regime, and water quality (salinity, dissolved oxygen) - Phase 1 and 2
2. Quantify species composition, distribution and density of juvenile and adult nekton, and
3. Validate environmental flow recommendations in the lower tidal portion of the Brazos River using *historical* AND *current* data.

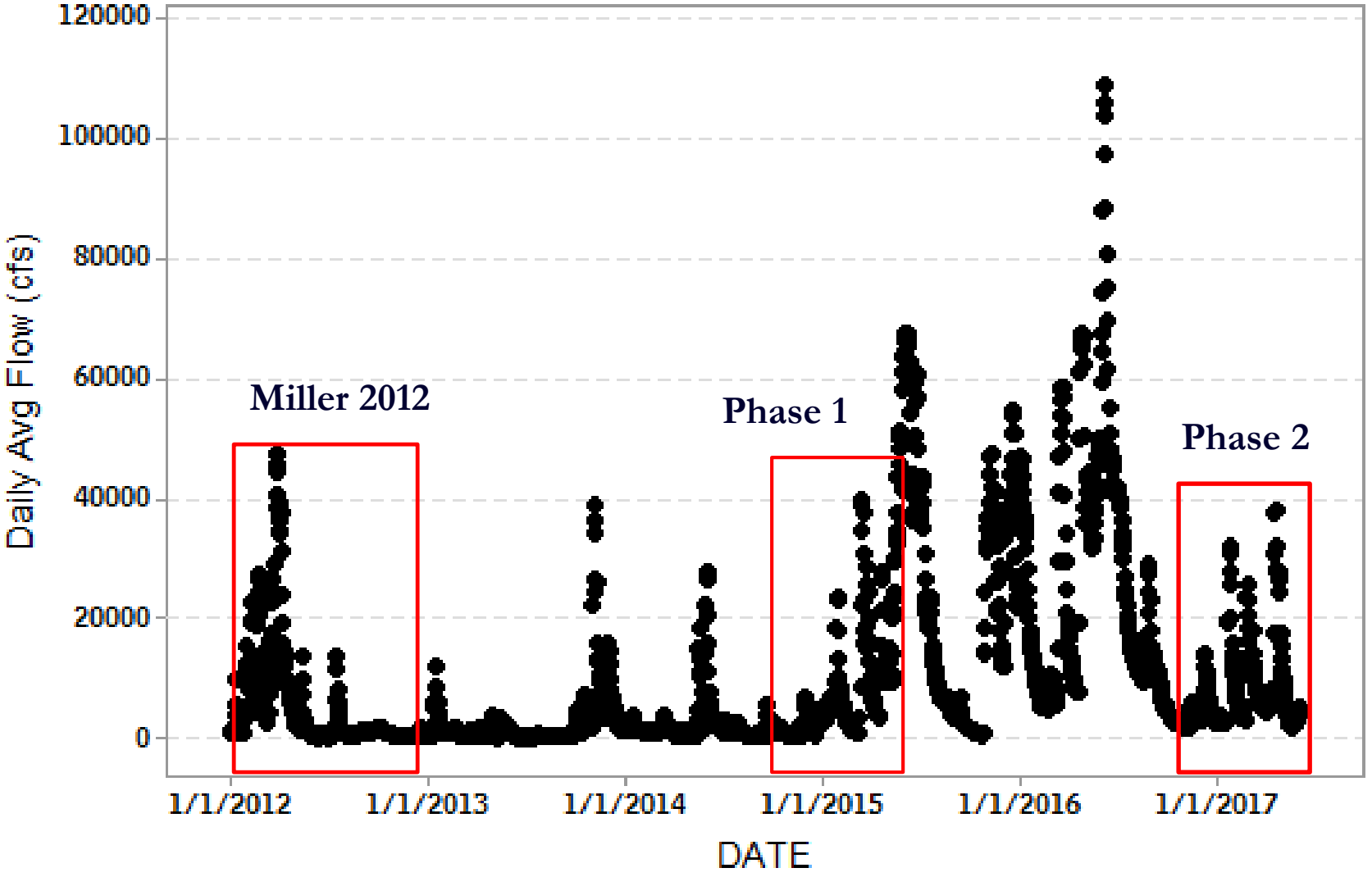

Study Area
B42
B36
Upper
B31
B25
B22
Middle
B15
B10
Lower
B05
B01
Richwood
Lake Jackson
Clute
STRATTON RIDGE OIL FIELD
Oyster Creek
Dow Chemical Company
Jones Creek
Freeport
Quintana
Surfside Beach
Angleton
Danbury
Bonney
Rosharon
Bailey's Prairie
Site Type
Continuous
Primary
Secondary
1201 Upper Boundary
USGS Rosharon Gage
N
0 4.5 9 18 Kilometers
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Brazos River Delta

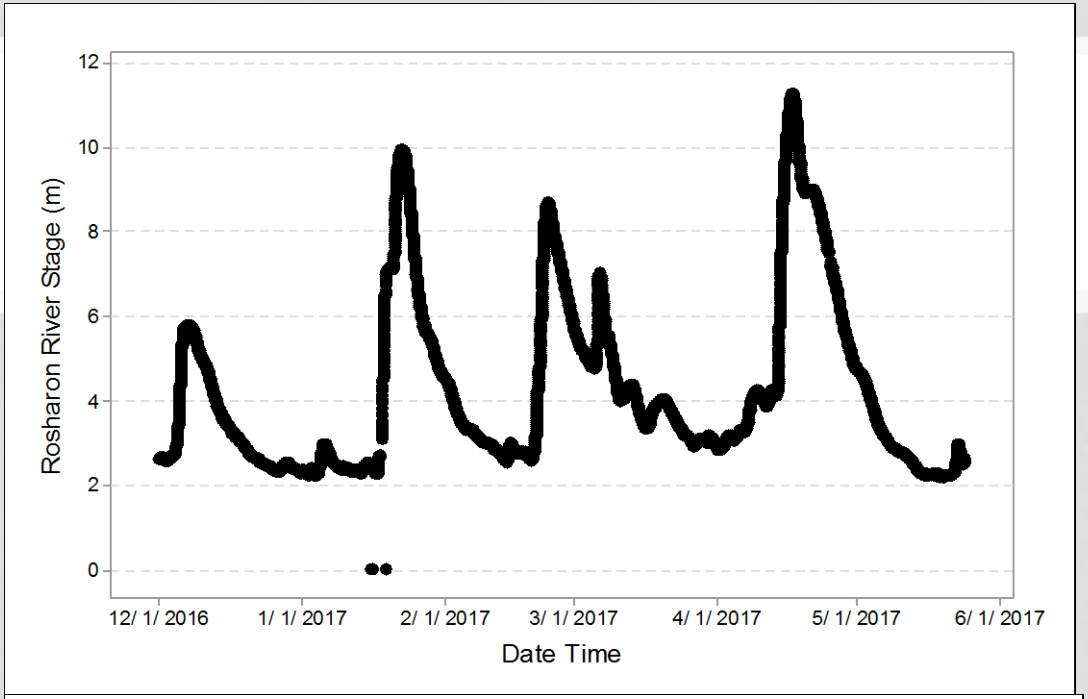
Gulf of Mexico

2016-2017 STUDY

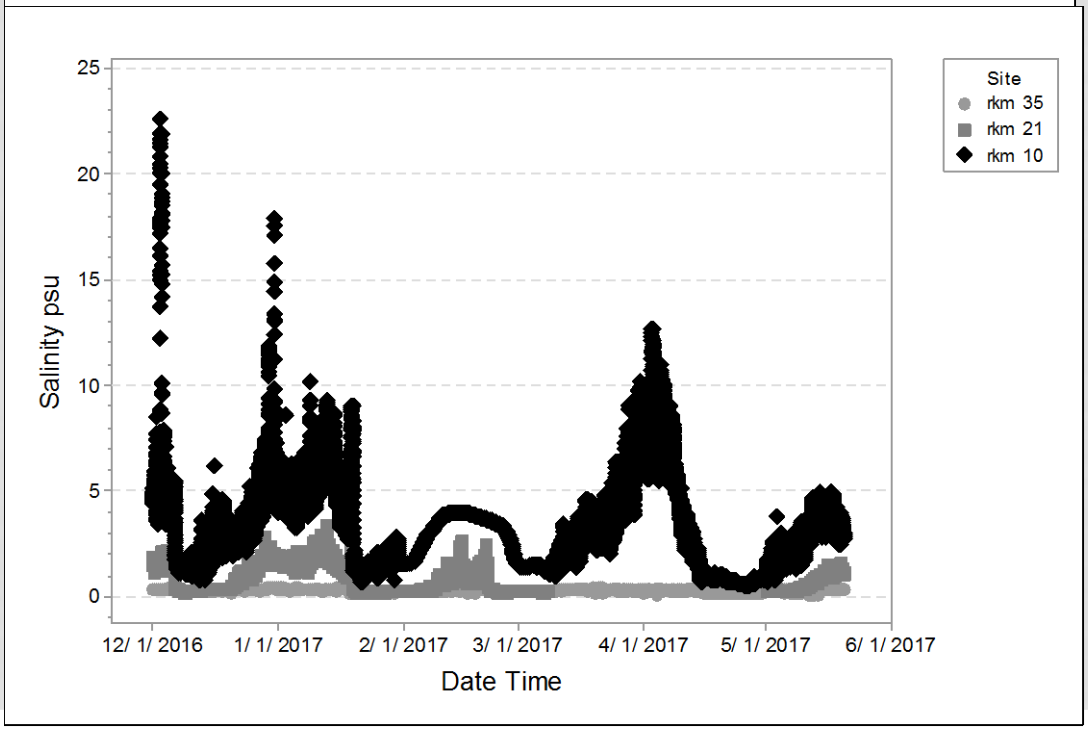
- **5 primary sites**; 1, 10, 22, 31, 42 rkm; 4 secondary sites (Nov 2014 - May 2015; Dec 16-May '17)
- Monitored various flow tiers.
- **Trawling** – (3 rep) 10 ft, 5 minute tow, ¼" mesh; (3 rep) 4 ft wide, 1/8" mesh in cod –end.
- **Renfro Beam trawl** – shoreline. Each primary site (3 reps; 1/8 inch mesh).
- **Water quality profiles** – 1, 5, 10, 15, 22, 25, 31, 36, and 42 rkm, temp, pH, sal, DO, NTU
- ***Continuous monitoring sondes****: rkm 10, 22, 36*


120000
100000
80000
60000
40000
20000
0
Daily Avg Flow (cfs)
Miller 2012
Phase 1
Phase 2
1/1/2012
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
DATE

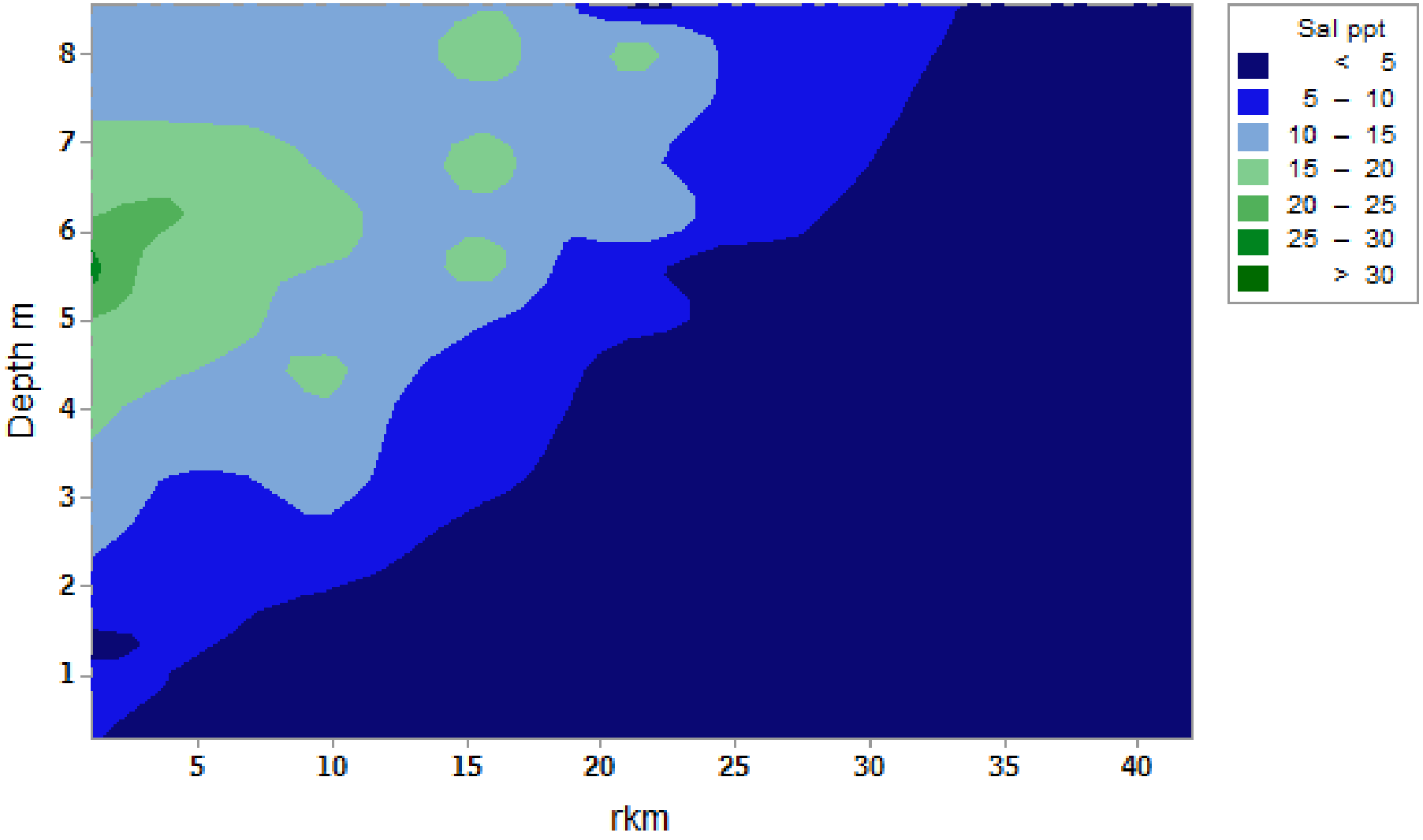
Rosharon gage



Downstream Salinity

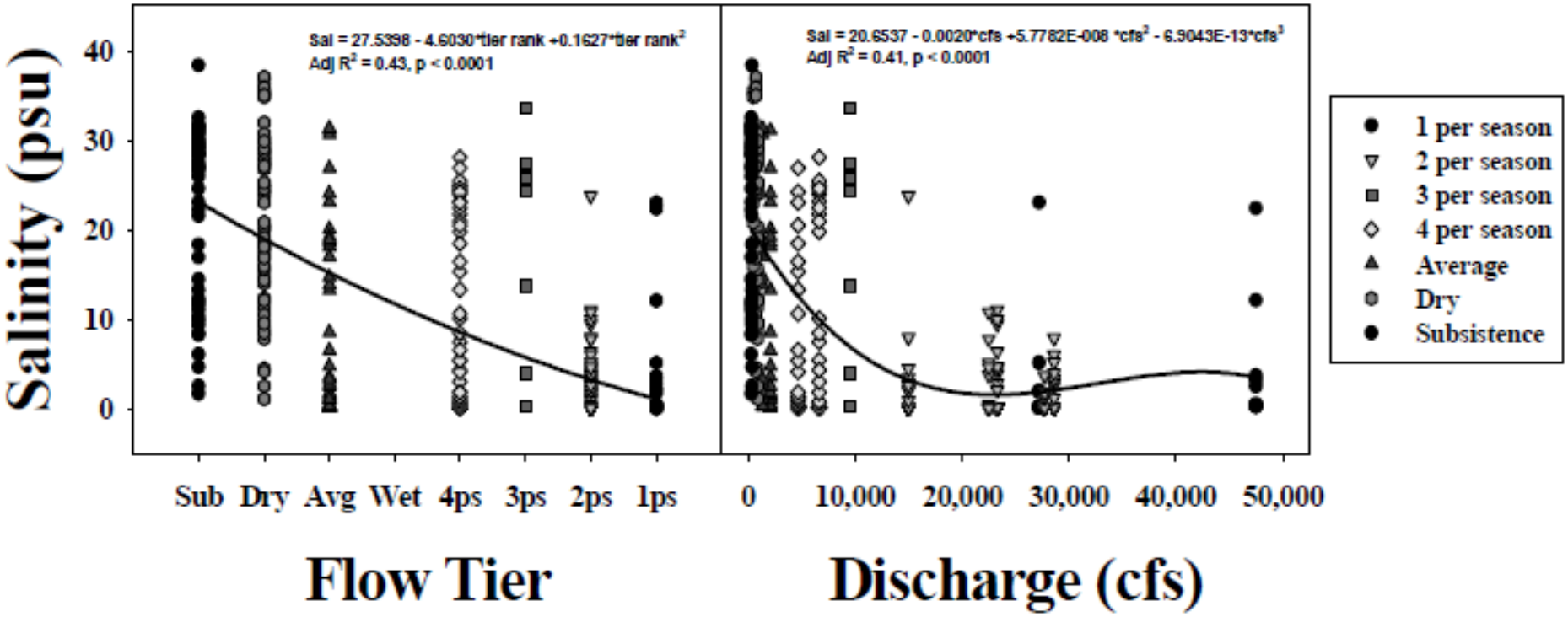


Contour Plot of Salinity vs Depth vs. River Kilometer



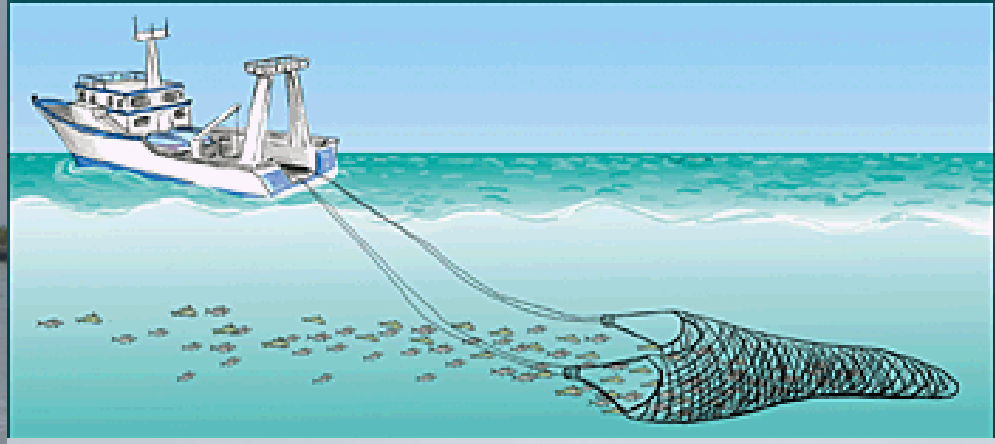
Current Study and Miller (2014) combined.

Significant relationship between salinity vs. flow tier and discharge



Otter Trawl


Environmental Institute of Houston

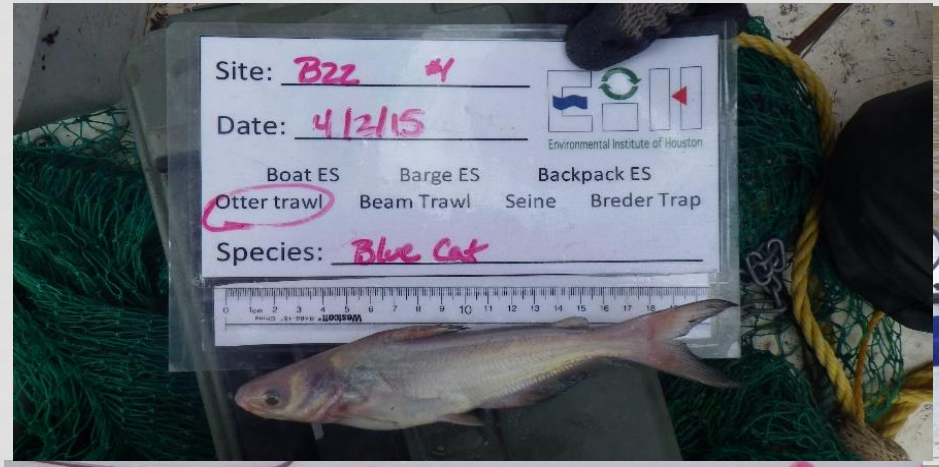



Environmental Institute of Houston
Twin Vee
EVINRUDE


12/20/2016 09:31

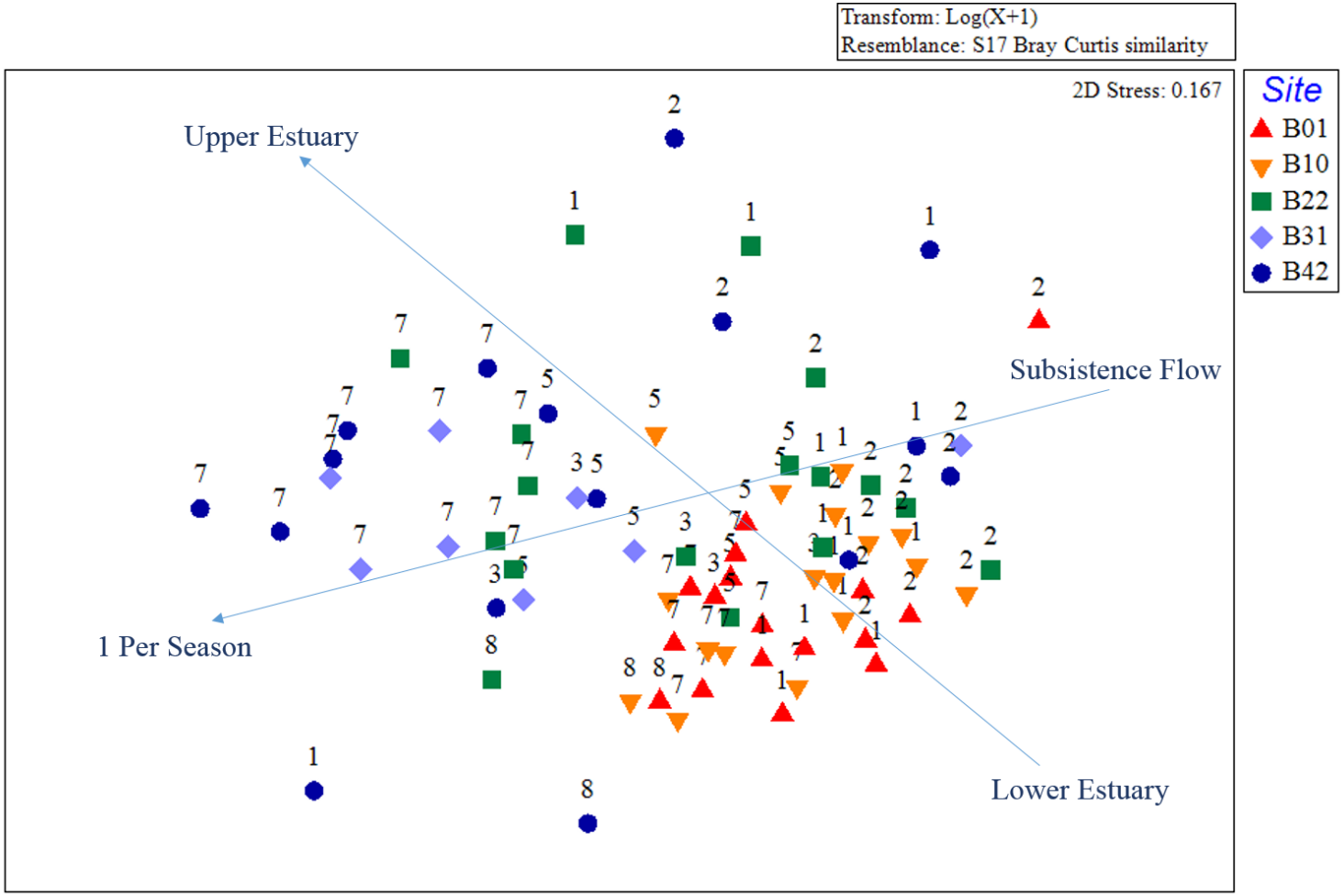
Beam Trawl


Renfro Beam Trawl
Zip-on sock with protective shroud, underside apron towing bar pockets.


Site: B22 #4
Date: 4/2/15
Environmental Institute of Houston
Boat ES
Barge ES
Backpack ES
Otter trawl
Beam Trawl
Seine
Breder Trap
Species: Blue Cat


pecies: Channel

Current (Phase 1) and Miller 2014 Study: Otter and Beam Trawl



NMDS plot for nekton abundance (log+1 transformed with Bray-Curtis resemblance) from 2012 and 2014-15 using combined otter trawl and beam trawl data. Relationships by Flow Tier (from top right to bottom left) and Site location (from bottom right to top left) are shown with general trend lines. Points are labeled by Flow Tier Category (1=Subsistence flow 2=dry base flow, 3=average wet flow, 5=four per season, 7=two per season events, and 8=one per season .

BRAZOS ESTUARY CONCLUSIONS

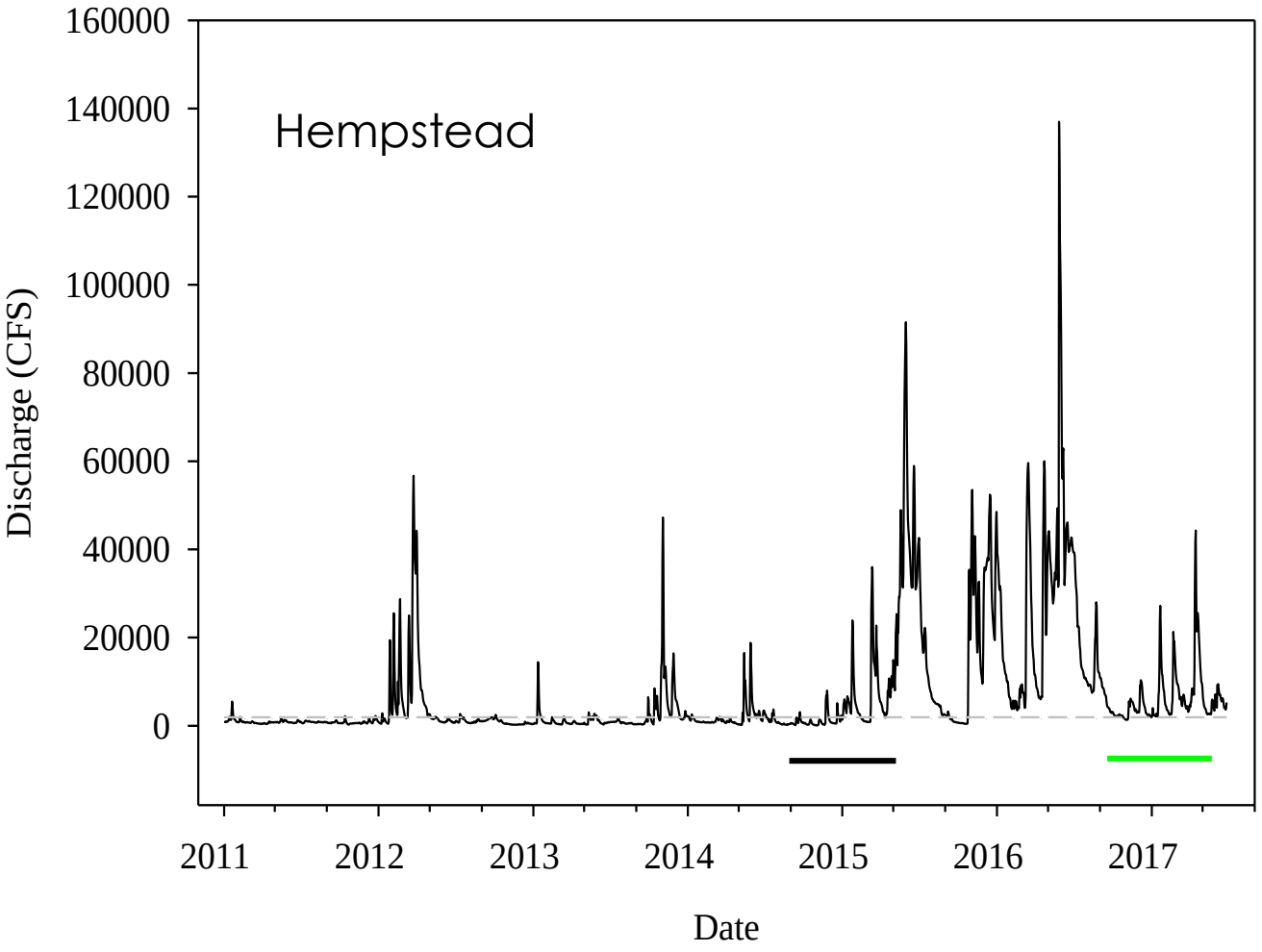
- Salinity and dissolved oxygen responds rapidly to changes in freshwater inflow.
- Probability of hypoxia lower when flow is high and salt wedge is reduced or pushed downstream.
- Species composition sensitive to salinity but some species exhibit strong seasonal response, i.e. overall proportion of each species may be less sensitive = broad tolerance to salinity changes?
- Latitudinal gradients related to salinity and dissolved oxygen are likely interacting with strong seasonal pulses of juvenile fish.

SAMPLING ACTIVITIES AND RESULTS

AQUATICS

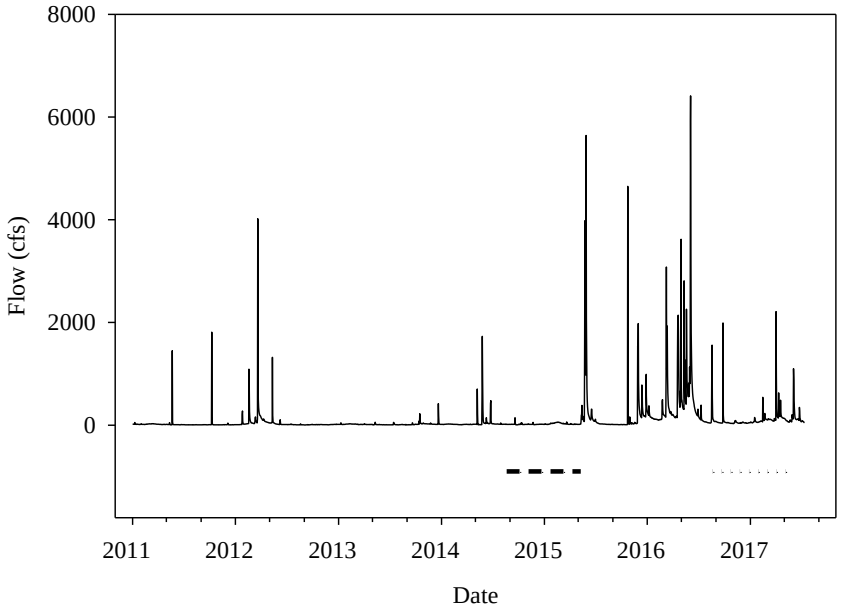
- Dr. Timothy Bonner

LOWER BRAZOS RIVER – HEMPSTEAD AND ROSHARON

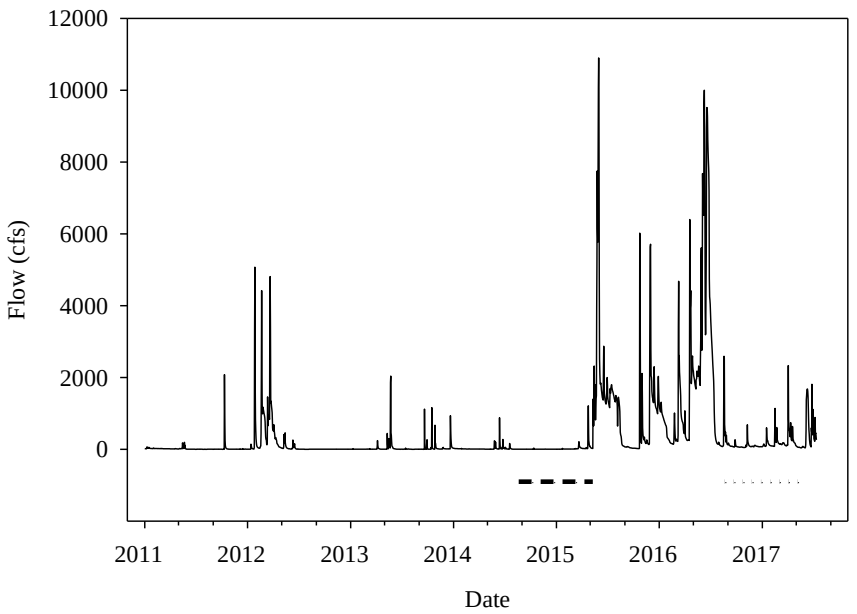


HYDROGRAPHS

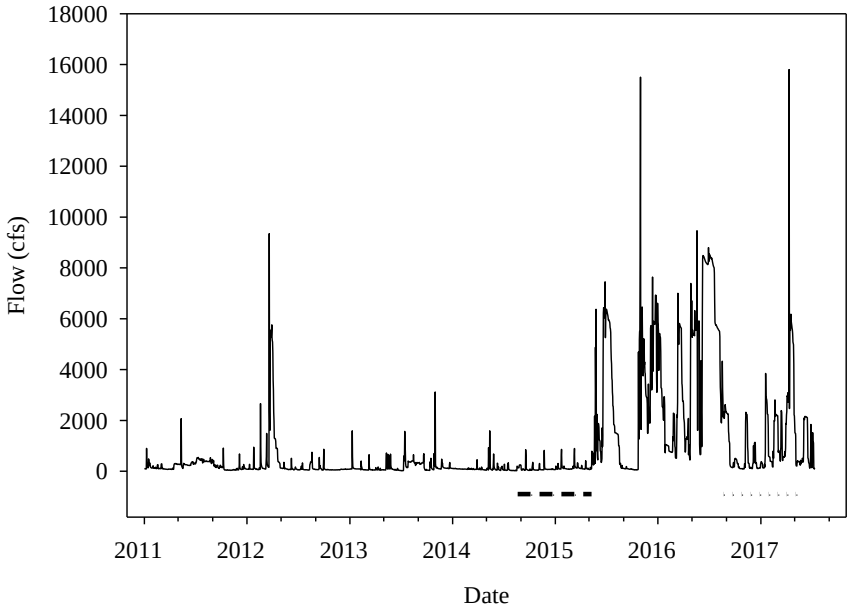
Leon River – Gatesville USGS 08100500



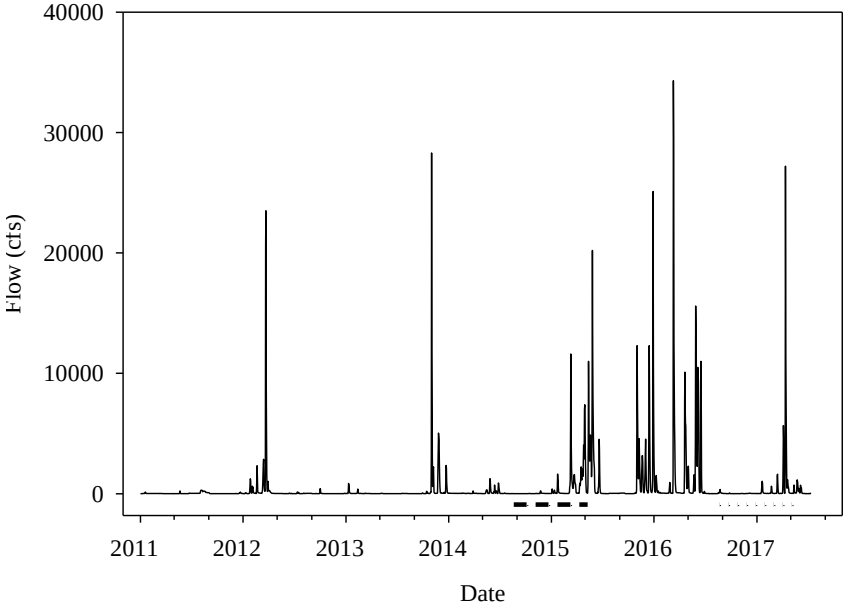
Lampasas River – Kempner USGS 08103800



Little River – Little River USGS 08104500

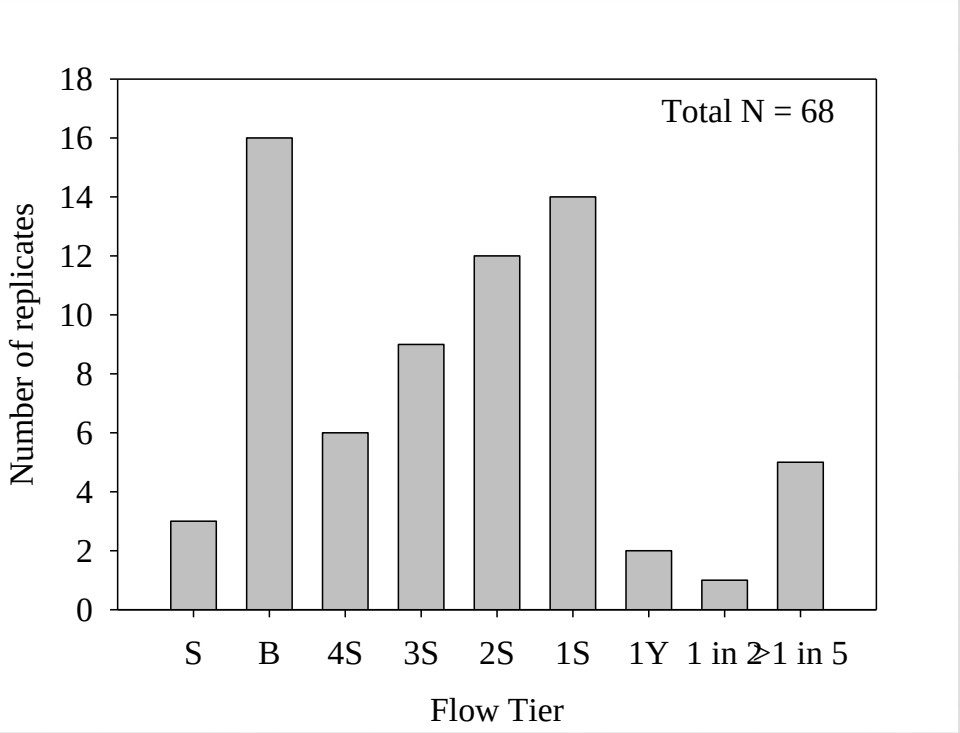


Navasota River – Easterly USGS 08110500



BRAZOS RIVER 2014 - 2017

- 40 fish species; 15,121 fishes
- 9 orders of macroinvertebrates; 51,442 macroinvertebrates

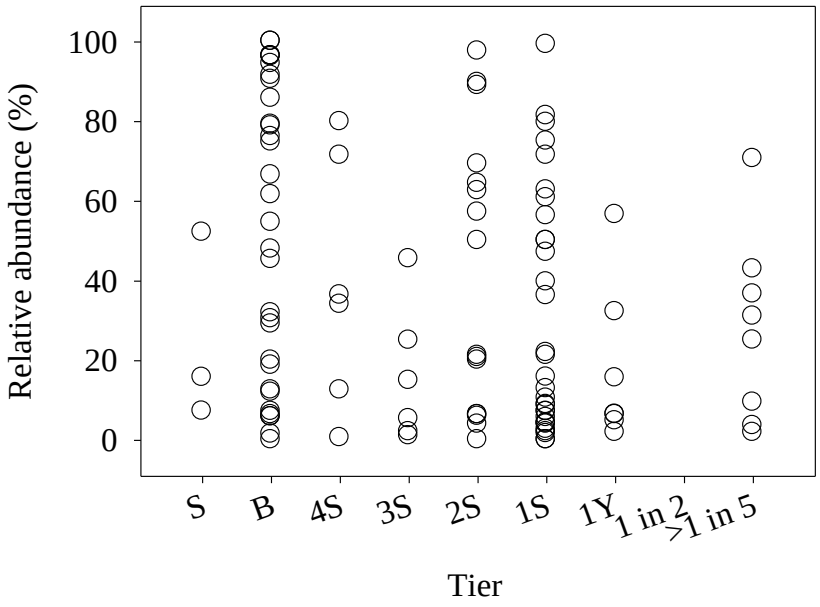


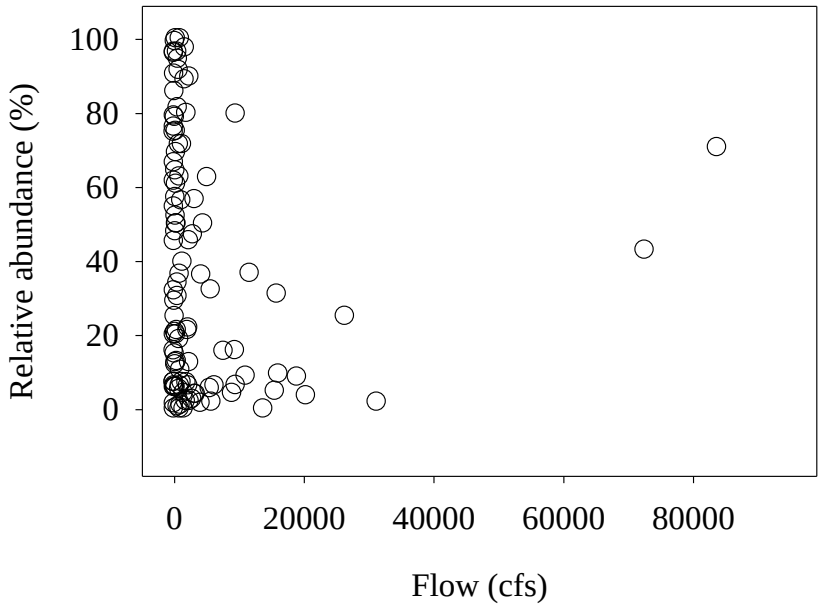
ALL BASINS 2014 - 2017

- Sampled habitats (N = 362, with 716 seine hauls)
  - 130 riffles
  - 153 runs
  - 56 backwaters
  - 23 pools
- Fish: 59 species; *N* = 43,349
- Aquatic macroinvertebrates (379 Hess samples)
  - 9 orders; *N* = 115,228

UNIVERSAL TRENDS

- None across all basins.
- Swift-water specialist example below.





- However, with Round Two data we had sufficient replication to look at patterns among sites.

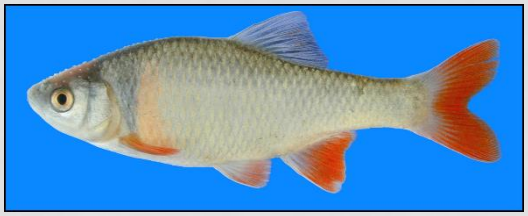
LEON AND LAMPASAS RIVERS

- Riffles: decreases in Central Stoneroller (unexpected) relative abundances and Orangethroat Darter (unexpected) densities between pre-flood and post-flood (unexpected)

- Macroinverts: increased densities of total numbers (unexpected) and in EPT (expected) between pre-flood and post-flood.

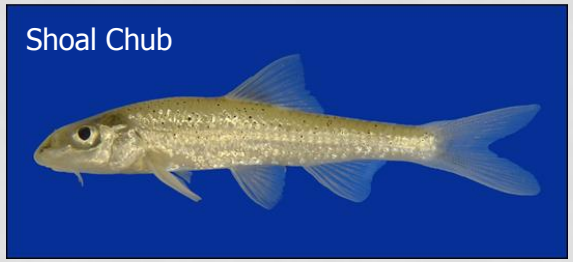
LITTLE RIVER

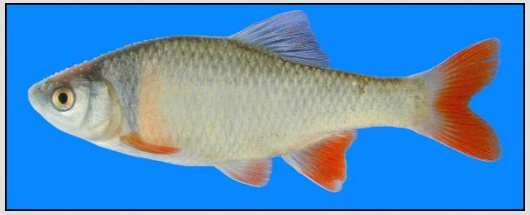
- Riffles:
  - increases in Red Shiner (unexpected) relative abundances
  - decrease in Central Stoneroller (unexpected) relative abundances, Orangethroat Darter (unexpected) and Central Stoneroller (unexpected) densities between pre-flood and post-flood



BRAZOS RIVER-HEMPSTEAD AND ROSHARON

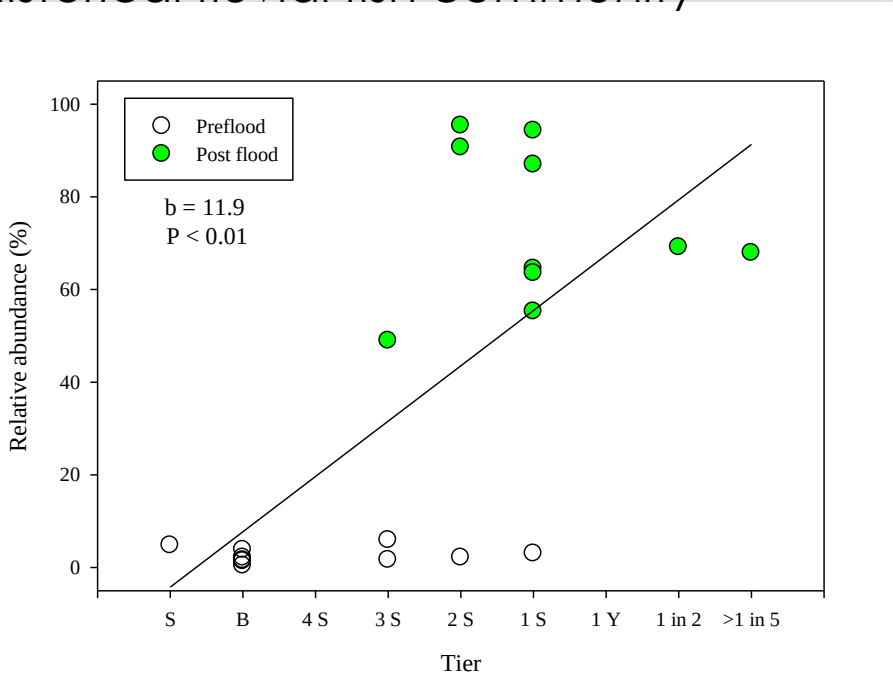
- Runs: Large scale shift in fish community
  - Increases in fluvial specialists Silverband Shiner (expected) and Shoal Chub (expected) in relative abundances
  - Decreases in Red Shiner (expected) in relative abundances and densities

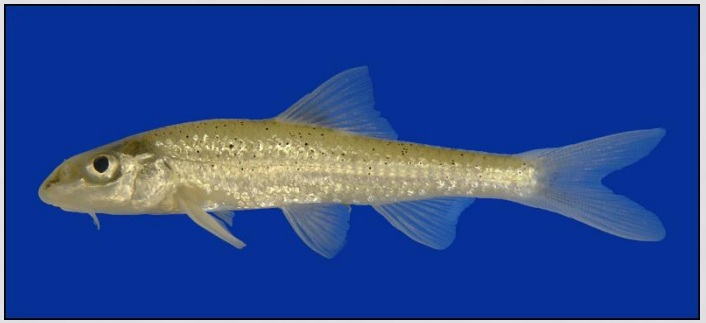




BRAZOS RIVER-HEMPSTEAD AND ROSHARON

- Historical fluvial fish community

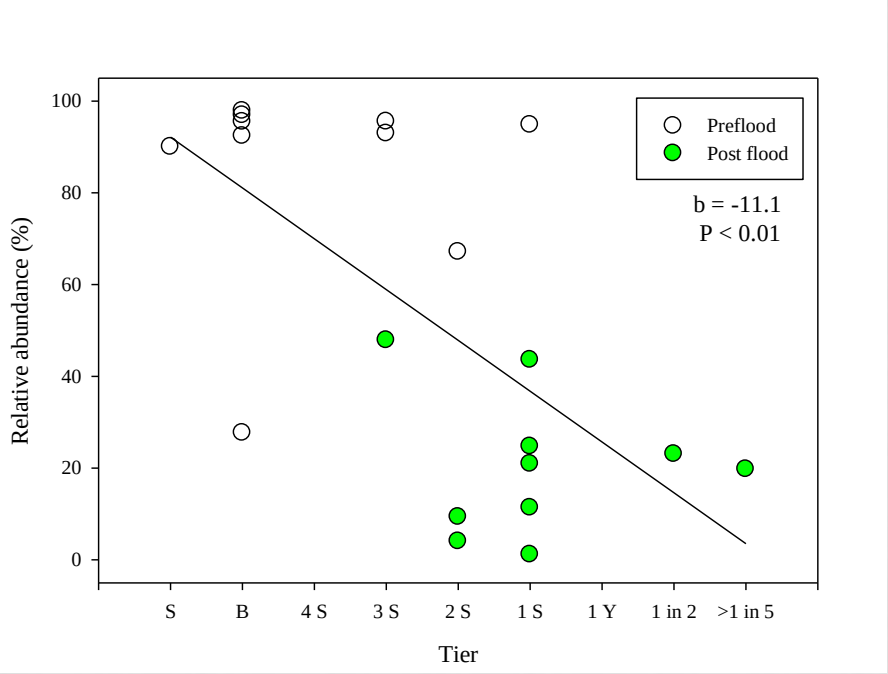


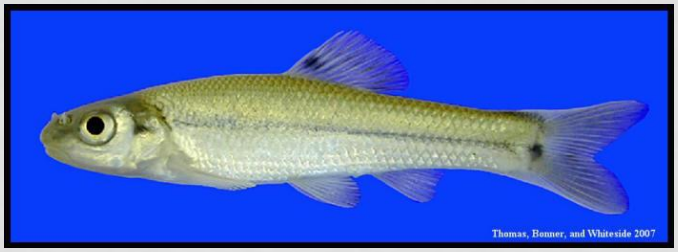


Mechanisms: Not sure, but more successful reproduction and recruitment (expected)

BRAZOS RIVER-HEMPSTEAD AND ROSHARON

- Generalist fluvial fish community
  - Historically low abundance
  - Mechanism: wash out? Failed repro and recruitment



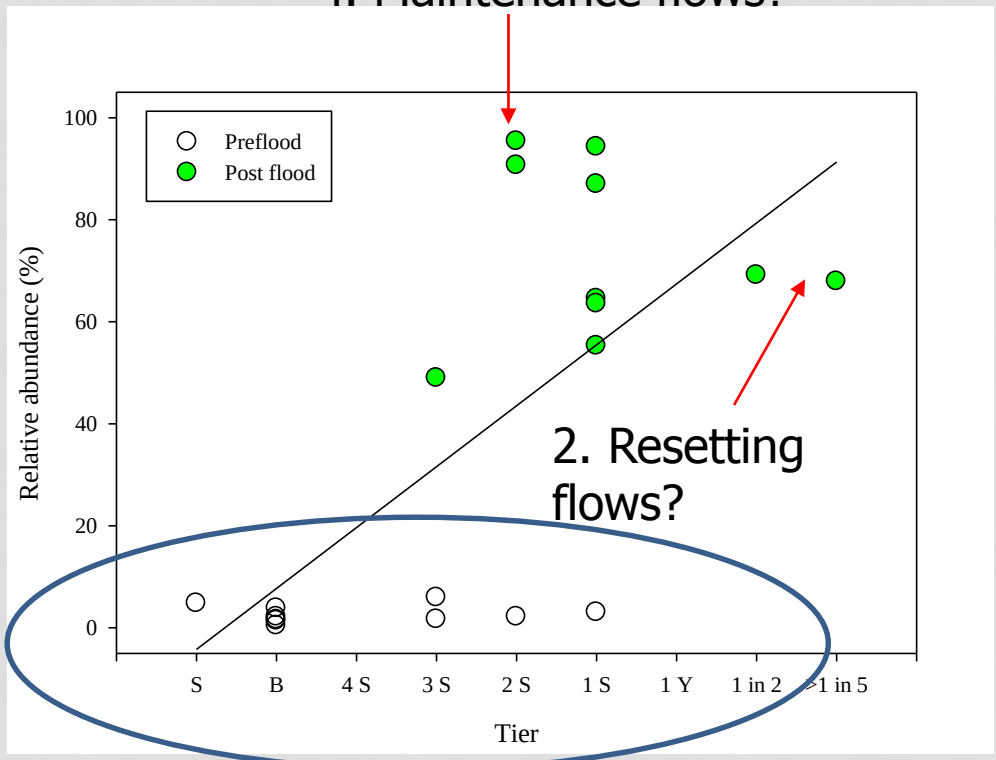


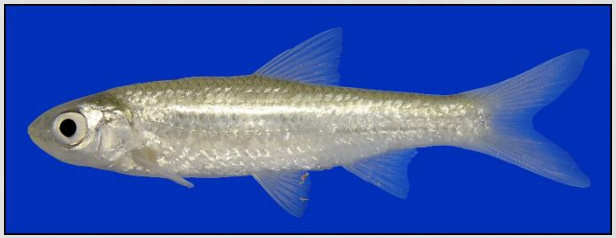
1 per season flow tiers were associated with lower relative abundances of *C. lutrensis* in runs, when compared to base and 3 per season flow tiers.

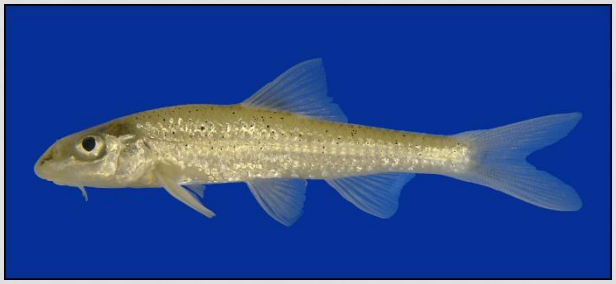
BRAZOS RIVER-HEMPSTEAD AND ROSHARON

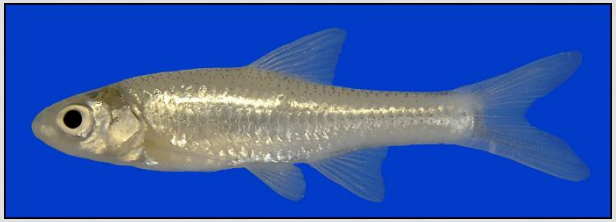
- Ecological functions of flow magnitude may be dependent on previous flow conditions

3. With resetting flows, will flow tiers have an effect?
4. Maintenance flows?









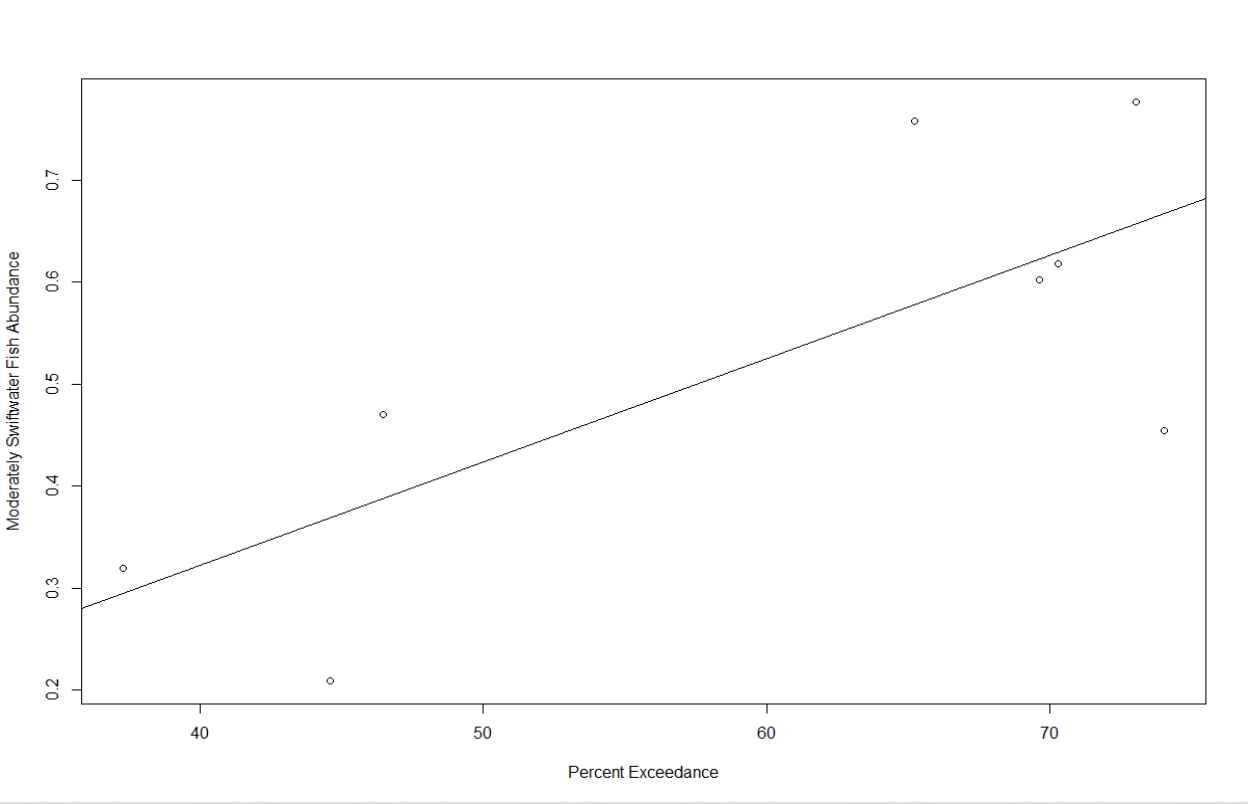
1. No effect among flow tiers

SUMMARY OF RESULTS

Combination / Individual Sites per basin	Fish and Macroinvertebrate response (Community or species)							
	4/S	3/S	2/S	1/S	1/Y	1/2Y	1/5Y	Pre-flood vs. post-flood
GSA								
Medina River—Bandera and Guadalupe River—Comfort							√	√
Guadalupe River—Gonzales and Cuero and San Antonio River—Goliad				√				
Cibolo Creek—Falls City								√
San Marcos River—Luling				√				√
Brazos								
Leon River—Gatesville and Lampasas River—Kempner								√
Little River—Little River								√
Navasota River—Easterly							√	√
Brazos River—Hempstead and Rosharon			√	√				√

HISTORICAL DATA

- 105,151 fishes
- 67 species
- Habitat
  - 55 riffles
  - 77 runs
  - 53 pools
  - 67 backwaters



- Swift-water fishes vs. flow – Colorado Basin

SAMPLING ACTIVITIES AND RESULTS

FLOODPLAIN CONNECTIVITY

- Brad Littrell

IMPORTANCE OF FLOODPLAIN CONNECTIVITY

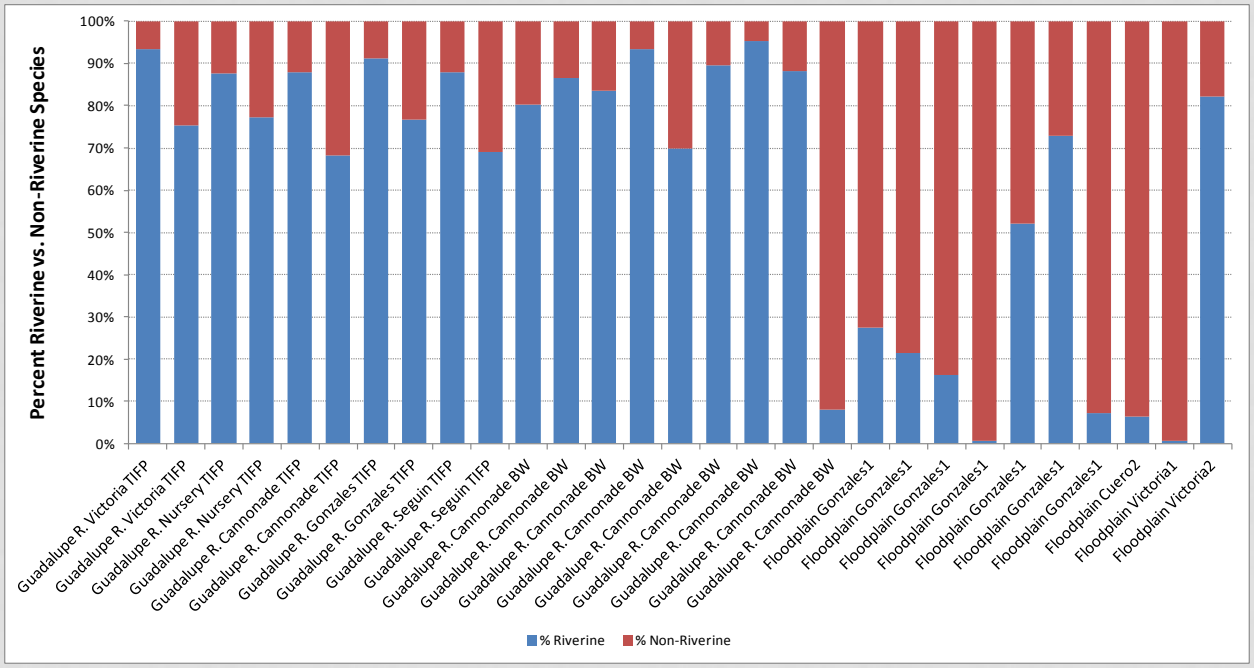
- Habitat for unique floodplain specialists
- Maintains basin-level diversity
- Provides important recruitment habitat for many species
- Source-sink dynamics
- Periodic connection is necessary to maintain water levels and allow for biotic exchange

Slough darter *Etheostoma gracile*

FLOODPLAIN SPECIALISTS

FISH COMMUNITY DATA

- Species richness ranged from 2 – 23 among floodplain collections
- Fish communities significantly different between floodplain and riverine collections



VICTORIA 2 CONNECTION POINT

- 4/1/2015 625 cfs

VICTORIA 2 CONNECTION POINT

- 2/15/2017 1730 cfs

VICTORIA 2 CONNECTION POINT

- 5/18/2017 1260 cfs

SAMPLING ACTIVITIES AND RESULTS

RIPARIAN

- Dr. Jacquelyn Duke

RECAP ROUND 1
STUDY HYPOTHESES

Riparian responses to flow:

- **Seedlings**
  - Distrib vs. TCEQ /BBEST flows
  - Distrib vs. *actual* flows
  - Survival vs. flows
- **Saplings**
  - Distrib vs. TCEQ /BBEST flows
  - Distrib vs. *actual* flows
  - Survival vs. flows

- **Mature trees**
  - Distributions reflect TCEQ/BBEST flow coverage (80% or more)
- **Community**
  - Relative abundance reflects riparian dominance

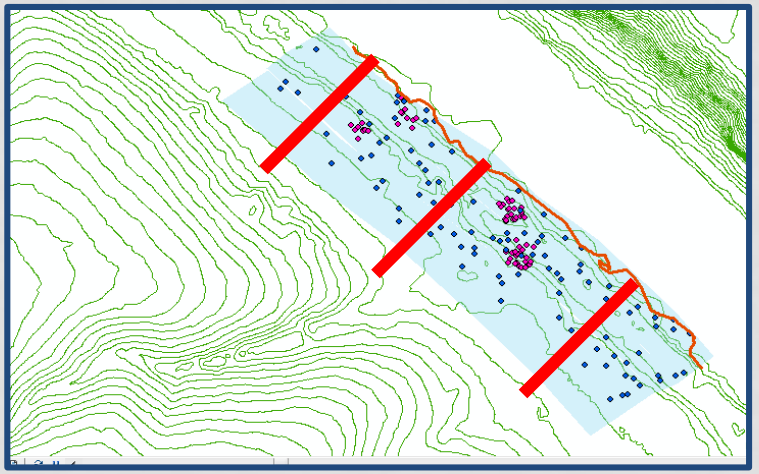
TRANSECT METHOD
(ROUND 1)

Pros

- Easily identifiable Species
- Tight linkage: life stages and flow
- Quick, simple field method
- Known distribution and width

Cons

- Limited community characterization
- Limited community temporal changes
- Stats-free



ROUND 2 – CORRIDOR METHOD

Community:

1) Biotic (woody and herb) and abiotic (steepness, soil type/class, sinuosity, channel width)

2) Relative Abundance *of grouped species (OBL, FACW, FAC, FACU)*

Within Sites Community Differences:

3) *Between tiered groups?*

4) *Between spring and fall?*

Between Sites:

5) *Community diffs between sites?*

6) *Result from abiotic factors?*

Across basins:

7) *Community diffs between sites across basins?*

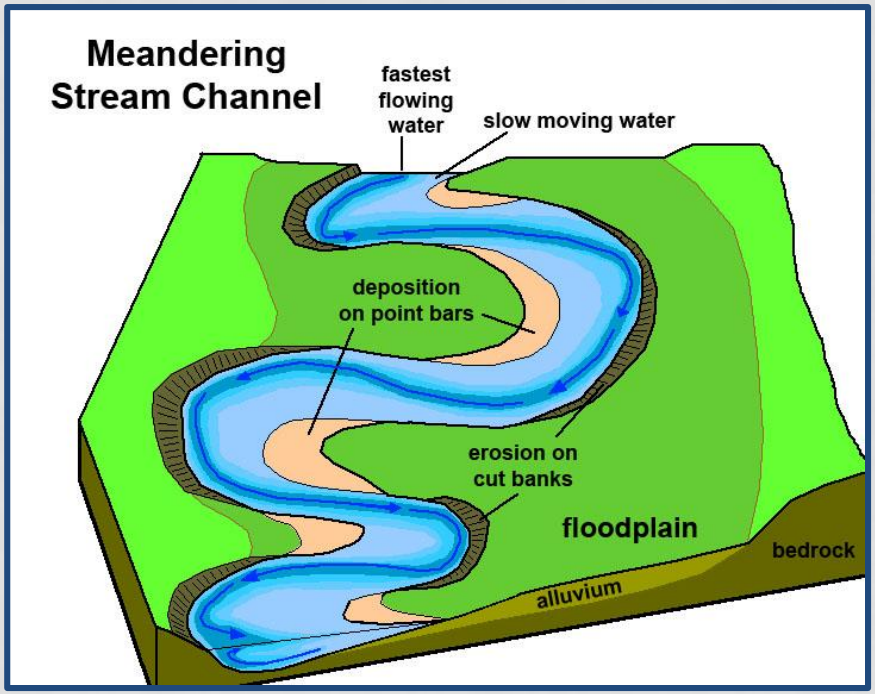


Image Credit: geologycafe.com

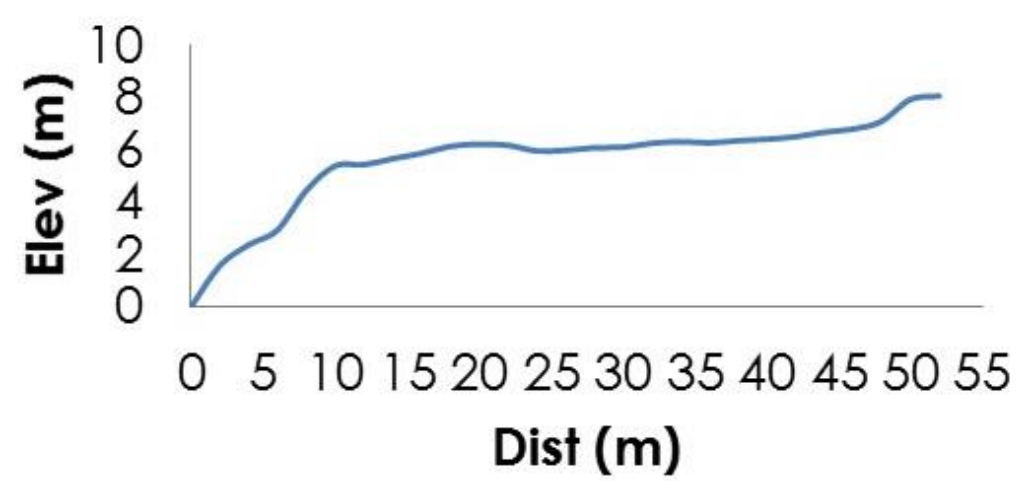
ROUND 2 – COMMUNITY DYNAMICS

8) *Stream discharges needed to inundate plots?*

9) *Do Flow Tier standards align with riparian needs?*

Recommendations:

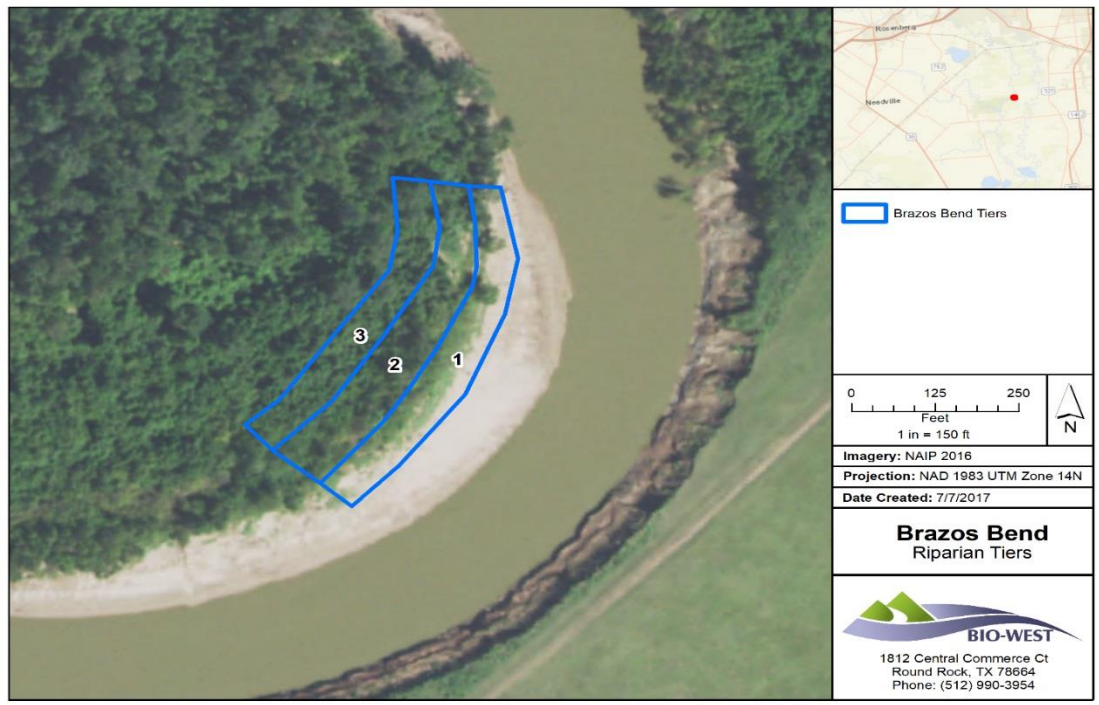
10) *Which method (longitudinal random vs. transects) is more beneficial for long-term monitoring?*



Site Profile

SAMPLING PROCEDURES

- Parallel tiers (lower, mid, upper)
- 2X2m random plots. Min/*tier*=25
- Woody veg counts, by size class:
  - Seedling, Sapling, Sapling older, Transition, Overstory (mature)
- Herb counts
- GPS elev. and distance to stream
- Mature tree counts and distrib



SAMPLING PROCEDURES CONTINUED

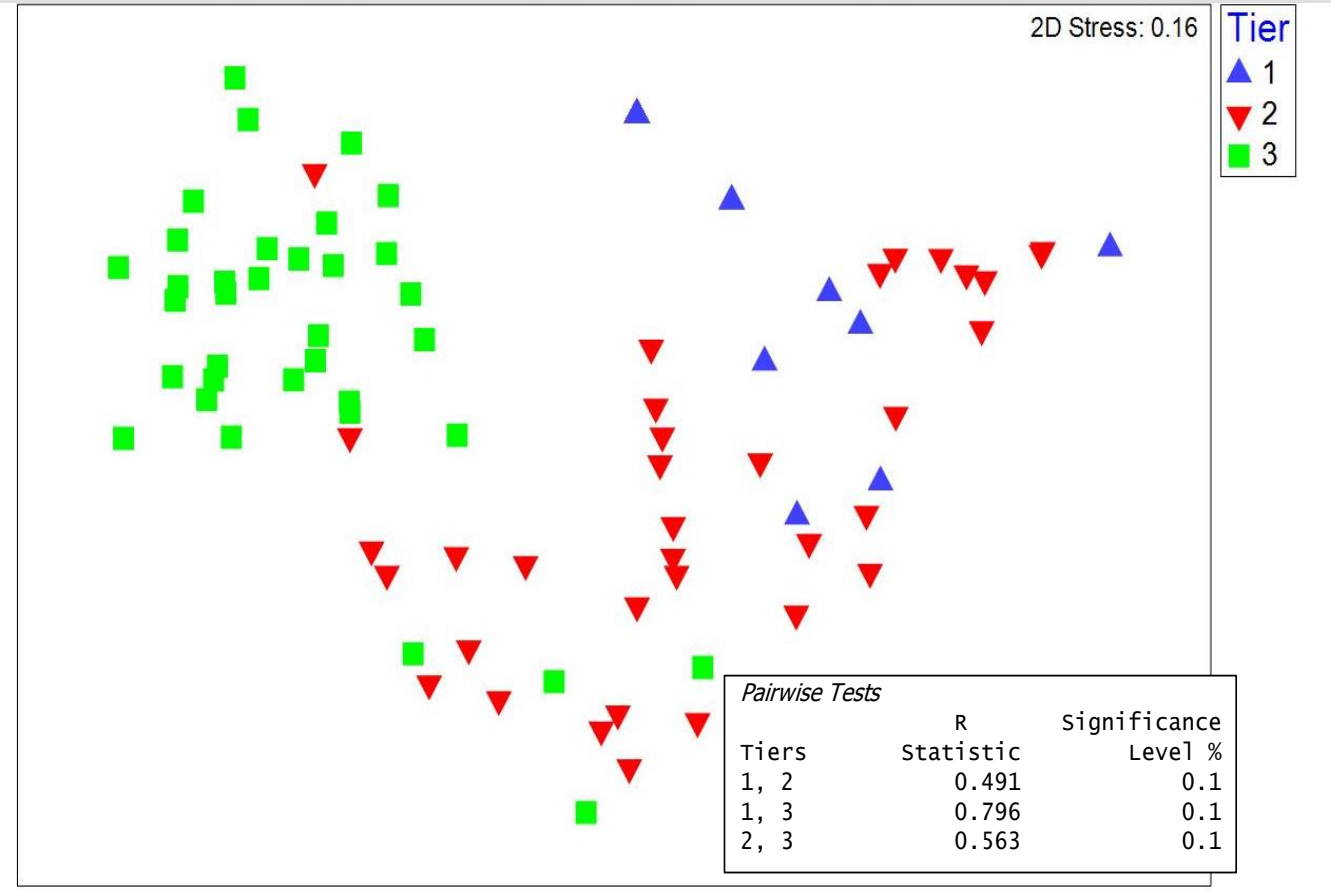
- Stats - community differences
- USGS Gauge Data and inundation modeling
- 2 Sites: Brazos Bend and Hearne

Photo Cred: Casey Williams

Photo Cred: Nick Castillo

EXAMPLES OF RESULTS

BRAZOS BEND– COMMUNITY ASSEMBLAGES BY TIER



nMDS – non-metric multidimensional scaling – ordination

ANOSIM - analysis of similarities (non-parametric)

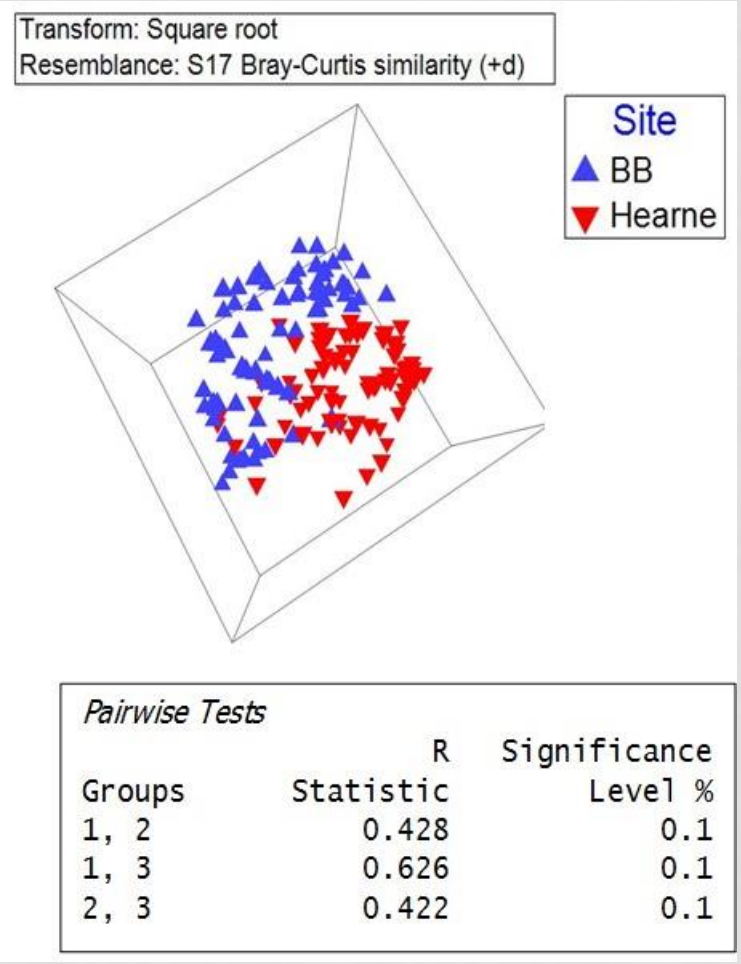
COMMUNITY ASSEMBLAGES ACROSS SITES

Group BB
Average similarity: 28.58

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Box elder	0.98	8.81	0.68	30.82	30.82
Black willow	0.94	5.89	0.46	20.62	51.44
Sycamore	0.91	5.14	0.50	17.98	69.42
cockleburr	1.31	4.85	0.30	16.98	86.40

Groups BB & Hearne
Average dissimilarity = 93.51

Species	Group BB Av.Abund	Group Hearne Av.Abund	Av.Diss	Contrib%	Cum.%
cockleburr	1.31	0.39	19.46	20.81	20.81
Box elder	0.98	0.25	9.69	10.36	31.17
Black willow	0.94	0.03	8.97	9.59	40.76
Sycamore	0.91	0.00	7.07	7.56	48.33
Pepper vine	0.34	0.32	5.18	5.54	53.87
Trumpcreeper	0.15	0.53	5.17	5.53	59.40

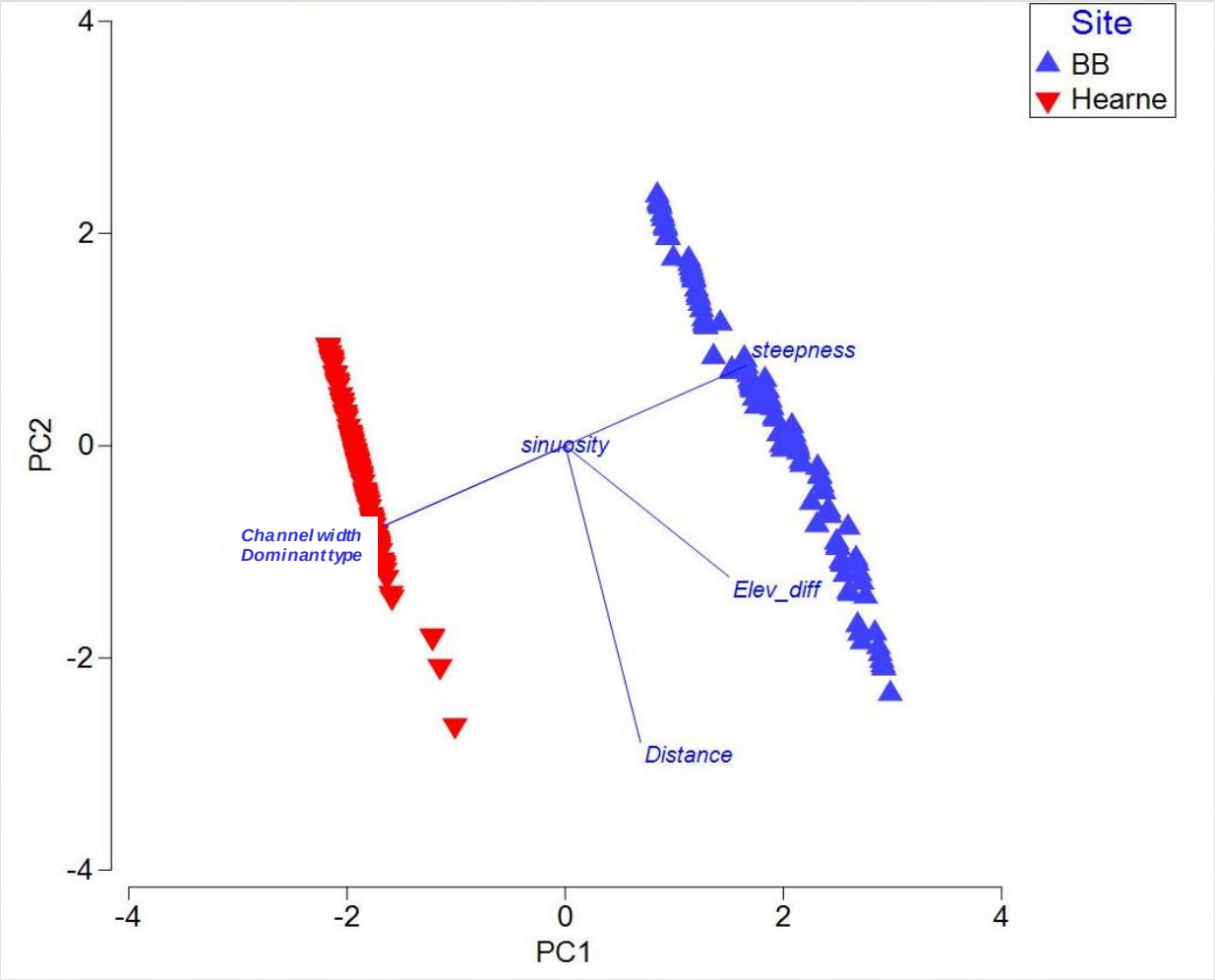


Pairwise Tests

Groups	R Statistic	Significance Level %
1, 2	0.428	0.1
1, 3	0.626	0.1
2, 3	0.422	0.1

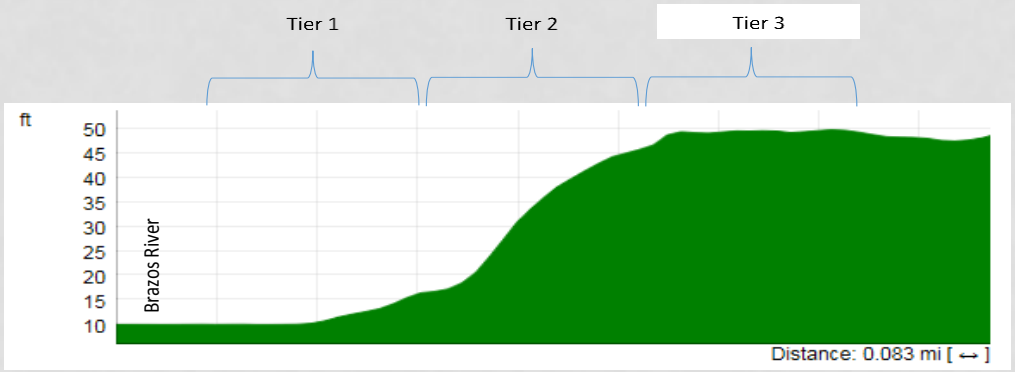
Simper – ranks species contributions to sample (dis)similarities

INFLUENCE OF ABIOTIC FACTORS



DO FLOW STANDARDS INUNDATE MATURE DISTRIBUTIONS?

Brazos Bend	Black Willow	Box Elder	Sycamore	Full Distribution	80% of Distribution
Low Elevation (cfs)	1581	27778	28907	1581	26864
High Elevation (cfs)	29009	35161	32826	35161	



Gauge Location	Study Site	Season / Time Period	Subsistence (cfs)	Hydrologic Condition	Base (cfs)	Dry Pulse (cfs)	Average Pulse (cfs)	Wet Pulse (cfs)
Rosharon	Brazos Bend	Winter	430	Dry	1,140	9,090	9,090	13,600
		Winter	430	Avg	2,090	9,090	9,090	13,600
		Winter	430	Wet	4,700	9,090	9,090	13,600
		Spring	430	Dry	1,250	6,580	6,580	14,200
		Spring	430	Avg	2,570	6,580	6,580	14,200
		Spring	430	Wet	4,740	6,580	6,580	14,200
		Summer	430	Dry	930	2,490	2,490	4,980
		Summer	430	Avg	1,420	2,490	2,490	4,980
		Summer	430	Wet	2,630	2,490	2,490	4,980

RECOMMENDATIONS

Pros

- Robust
- Monitoring aspect
- Quick (though generalized) snapshot of flow vs. needs
- Randomization allows for stats analysis
- Applicable across basins

Cons

- No linkage of individuals to within-season flow events
- May miss actual riparian distribution
- Requires secondary mature-tree sampling and refinement
- 3 tiers too general; indicator species distrib more accurately estimate flow needs

TAKE HOME

- Combining the two methods enhances each
- TCEQ flows are inconsistent in meeting riparian needs
- Further studies should span the growing season

ENVIRONMENTAL FLOWS VALIDATION METHODOLOGY

APPLICATION

- Ed Oborny

STUDY CONCLUSIONS

- Aquatics
  - Fish and macroinvertebrates are:
    - Good ecological indicators for water quality and aquatic habitat for evaluating subsistence and base flows.
    - Ecological indicators for pulse flows within the range of the TCEQ flow standards inconclusive. (*Exceptions – 1 per season events*)
  - Major flood events shape the aquatic community.
    - Follow up monitoring after major shifts might serve as the ecological linkage of fish and macroinvertebrates to smaller pulses.

STUDY CONCLUSIONS

- Floodplain Connectivity
  - Strong ecological indicator relative to pulse flows, water quality.
  - Most recent floodplain features connected with existing TCEQ flow standards in the GSA Basin.
    - Brazos - To Be Determined
- Riparian
  - Strong ecological indicator relative to pulse flows.
  - Larger pulses than established TCEQ flow standards are generally needed to support the existing riparian communities.
- Brazos Estuary
  - Established baseline characterization
  - Ecological relationship to flow at Rosharon gage remains inconclusive at this time.

ENVIRONMENTAL FLOWS VALIDATION METHODOLOGY

- Two main objectives
  - To inform and refine validation methodologies with the goal of having a scientifically defensible approach for testing TCEQ environmental flow standards.
  - To provide the BBASC with information on how application of these methodologies might validate or suggest refinement for existing TCEQ flow standards at select basin sites.

ENVIRONMENTAL FLOWS
PROPOSED VALIDATION METHODOLOGY

- Standardized approach
- Incorporates multiple ecological components
  - **Level I – Aquatics**
  - **Level II – Floodplain Connectivity**
  - **Level III – Riparian**
- Simplified desktop and field activities

ENVIRONMENTAL FLOWS
PROPOSED VALIDATION METHODOLOGY

Level 1: Aquatics

- ***A. Question:*** Does the study reach have important aquatic resources (native fish communities, endangered or threatened species, recreational or commercial fisheries, unique instream habitats, etc.) and if so, what is the BBASC goal for maintaining the current assemblage and community composition?

- ***B. Decision/Goal:*** If "yes," and a goal* is established, then proceed with the subsistence and base-flow recommended aquatic evaluation (C). If "no," do not consider aquatics in the validation evaluation.

- ***C. Flow Evaluation:*** Based on the results of this study, fish and macroinvertebrate community data could be compared to the pre-established goal and a direct comparison made. If certain sites do not have recent seasonal biological data, then an on-site aquatic evaluation would consist of a field-sampling effort.

- ***D. Long-term monitoring recommendation:*** Based on the results of the evaluation and potential of future projects affecting this site, determine whether a seasonal, long-term monitoring of the aquatic community is warranted for future adaptive management decision making.

ENVIRONMENTAL FLOWS
PROPOSED VALIDATION METHODOLOGY

HYPOTHETICAL GOALS

- ***Aquatics:*** Fish community density and relative abundance will be maintained within 25% of the existing native fish community structure as represented by data collected in a rolling 10-year period leading up to the present time.

- ***Floodplain Connectivity:*** Recent downstream oxbows are important to support the fisheries community and a minimum of 75% of recent downstream oxbows should be connected in the spring and fall for a minimum period of two consecutive days.

- ***Riparian:*** 80% of the existing riparian community at the site is inundated in the spring and fall for a minimum duration of 3–4 days.

ENVIRONMENTAL FLOWS
FLOW EVALUATION – BRAZOS RIVER AT BRYAN

Level 1 - Aquatics: Subsistence, Base and Pulse Flows:

- ***Standards:*** Seasonal TCEQ subsistence and base recommendations are 300 cfs, and 540 to 2,490 cfs, respectively. The TCEQ dry pulses relate to 1-per-season events and range from 2,060 to 6,050 cfs.
- ***Assessment:*** Biological sampling conducted via this study shows that the fish community within this study reach is within the hypothetical 25% goal compared to data collected over the past 10 years. A 1-per-season events trigger an ecological response for fish and macroinvertebrates.

- Adaptive management ***considerations***:
  - *Subsistence:* There is nothing in the existing dataset that warrants a consideration for adjusting subsistence flows in either direction at this time.
  - *Base:* There is nothing in the existing dataset that warrants a consideration for adjusting base flows in either direction at this time.
  - Maintain all 1-per-season pulses.

ENVIRONMENTAL FLOWS
FLOW EVALUATION – BRAZOS RIVER AT BRYAN

Level 2 – (Floodplain Connectivity): Pulse Flows

- ***Standards:*** TCEQ dry and average pulses range from 2,060 to 6,050 cfs and TCEQ wet-season pulses range from 2,990 to 10,400 cfs.
- ***Assessment:*** No biological sampling was conducted via this study to examine floodplain connectivity.

- Adaptive management ***considerations***:
  - *Pulse flows:* None, until the completion of the desktop and field investigations for this level.

ENVIRONMENTAL FLOWS
FLOW EVALUATION – *SAN ANTONIO RIVER AT GOLIAD*

Level 2 (Floodplain Connectivity): Pulse Flows

- ***Standards:*** TCEQ small pulses range from 1,520 to 2,320 cfs and large season pulses from 4,000 to 8,000 cfs.
- ***Assessment:*** Biological sampling conducted via this study show that to connect the recent floodplain feature downstream of the study site a discharge of 2,740 cfs is needed.

- Adaptive management ***considerations***:
  - There are no adjustments to the large seasonal pulses as they meet the floodplain connectivity goals and are required to meet the Level 3 riparian goals (next level).
  - Eliminate small TCEQ seasonal pulses as none of them connect this floodplain feature.
  - Increase the spring and fall small TCEQ pulses from 1,5270 and 2,320 cfs to 2,750 cfs in order for them to provide floodplain connectivity.
  - If small spring and fall pulses are increased, consider decreasing the TCEQ standards durations of 16 and 19 days, respectively to 3 or 4 days. Shorter durations have proven sufficient ecologically to support this ecological linkage.

ENVIRONMENTAL FLOWS
FLOW EVALUATION – BRAZOS RIVER AT BRYAN

Level 3 (Riparian): Pulse Flows

- ***Standards:*** TCEQ dry and average pulses range from 2,060 to 6,050 cfs and TCEQ wet-season pulses range from 2,990 to 10,400 cfs.
- ***Assessment:*** Riparian sampling conducted via this study shows that to inundate 80% of the existing riparian community approximately 4,450 cfs is needed.

- Adaptive management ***considerations***:
  - *Pulse flows:* Increase the fall dry and moderate TCEQ pulse standards from 3,230 to 4,450 cfs.
  - Consider decreasing the duration of days listed in the spring and fall wet pulse standards to **3 to 4 days**. Ecological data collected during this riparian study has shown an effective seed dispersal and wetting effect with inundation from 3 to 4 days. The current TCEQ standards large spring and fall pulses have durations of **14 and 10 days**, respectively. These durations may not be supportive of either dispersal or wetting with the possible reverse effect of drowning out seedlings and saplings.

ENVIRONMENTAL FLOWS
AVAILABLE DATA * from this study

Lower BRAZOS SB 3 TCEQ Environmental Flow Standard Sites	Level 1 Aquatics	Level 2 Floodplain Connectivity	Level 3 Riparian
Brazos River at Waco			√
Leon River at Gatesville	√		√
Lampasas River near Kempner	√		
Little River near Little River	√		
Little River near Cameron			√
Brazos River at SH 21 near Bryan			√
Navasota River near Easterly	√		
Brazos River near Hempstead	√		
Brazos River at Richmond			
Brazos River near Rosharon	√		√
San Bernard River near Boling			

- Does not preclude an assessment of these other sites by the BBASC.
- Recent biological data from other sources could just as easily serve to inform Level 1 (Aquatics) assessments at locations not covered by this study.
- Secondly, each level has desktop and field assessments designed to take minimal effort to inform the completion of this approach for Level 2 and 3.

ENVIRONMENTAL FLOWS
FUTURE RESEARCH AND MONITORING RECOMMENDATIONS

- SB3 Applied Research
  - Post flood community shift aquatics
  - Freshwater mussels
  - Channel morphology
  - Brazos estuary
- Long-term Monitoring
  - Each component – flow driven
    - Select sites in each basin

QUESTIONS / COMMENTS?

- Acknowledgements
  - Landowners
  - TWDB
  - River Authorities
  - BBASC and BBEST
  - TPWD and TCEQ
  - Volunteers